

2/parts

TITLE OF THE INVENTION
SPECIFICATION

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HOT PLATE AND CONDUCTIVE PASTE

5 ~~TECHNICAL FIELD~~

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The present invention relates to a hot plate, which uses a ceramic substrate, and a conductive paste.

10 ~~BACKGROUND ART~~

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During a semiconductor fabrication process, for example, when heating and drying a silicon wafer subsequent to the application of a photosensitive resin, a heating apparatus, which is referred to as a hot plate, is normally used.

In recent years, substrates made of ceramic, such as alumina, is often used to form a hot plate. A resistor, which functions as a conductive layer and which has a predetermined pattern, is formed on one side of the alumina substrate. A terminal connection pad is formed on part of the resistor. Such conductive layer is formed by applying, heating, and bonding an alumina substrate silver paste to the substrate. Subsequently, a terminal pin is soldered to the pad, and the terminal pin is connected to a power source by a wire. A silicon wafer, which is a heated subject, is placed on an upper surface of the hot plate. When the resistor is energized in this state, the silicon wafer is heated to 100°C or higher.

A conductive paste including 60wt% to 80wt% of silver, 1wt% to 10wt% of glass frit, the base of which is lead boron

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silicate, 1wt% to 10wt% of a binder, and 10wt% to 30wt% of a solvent is often used to form a conductive pattern layer (refer to Japanese Unexamined Patent Publication No. 4-300249). Glass frit, which is a secondary component, is especially required to obtain the optimal adhesion for the conductive pattern layer.

When applying the above conventional lead paste directly to a ceramic substrate, such as an aluminum nitride substrate or a silicon carbide substrate, the following shortcomings occur. The heat produced when bonding the paste causes the oxides in the paste to react with aluminum nitride and produce a large amount of alumina and nitrogen gas. This is considered to occur mainly because of the large amount of oxides, especially lead oxide, in the glass frit. In this case, the high pressure of the nitrogen gas produced during the bonding of the paste forces the nitrogen gas to pass through the grain boundary of the silver grains toward the exterior of the conductive pattern layer. As a result, the conductive pattern layer is apt to expand and the accuracy for forming the pattern decreases.

Further, depending on the usage of the hot plate, there may be cases in which it is desired that the specific resistance of the conductive pattern layer be increased. In such case, if the amount of silver grains in the paste is relatively decreased to relatively increase the amount of glass frit, the ratio of the conductive components occupying the conductive pattern layer would decrease and, as a result, increase the specific resistance.

Simply employing this method would, however, most likely increase the amount of nitrogen gas produced when

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bonding the paste and cause the conductive pattern layer to expand.

~~DISCLOSURE OF THE INVENTION~~

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It is an object of the present invention to provide a hot plate having a conductive pattern layer that expands little, has superior adhesion, and has a large specific resistance and to provide a conductive paste optimal for the manufacturing of such hot plate.

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A first perspective of the present invention is a hot plate that uses a ceramic substrate provided with a conductive layer. The conductive layer includes ruthenium oxide, glass frit, and noble metal grains.

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The conductive layer includes ruthenium oxide. Thus, reaction between the glass frit and the ceramic substrate is suppressed even if the added amount of the glass frit is relatively large (10wt% or greater relative to the noble metal) to increase the specific resistance. This prevents expansion of the conductive layer. Accordingly, the conductive layer has a specific resistance that is $10\mu\Omega\cdot\text{cm}$ or greater. Further, it is considered that the ruthenium oxide itself functions to increase the specific resistance.

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It is preferred that the ceramic substrate includes ruthenium oxide, bismuth or its oxide, glass frit, and noble metal grains. By adding bismuth or its oxide, reaction between the glass frit and the ceramic substrate is suppressed. Thus, the conductive layer has superior adhesion.

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It is preferred that the ceramic substrate be a

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ceramic nitride substrate or a ceramic carbide substrate. The employment of a ceramic nitride substrate or a ceramic carbide substrate improves thermal conductivity and high-temperature heat resistance. The employment of the aluminum nitride substrate, which especially has superior heat resistance and high thermal conductivity, enables the hot plate to withstand usage under high temperatures and the hot plate is thus practical.

10 It is preferred that the glass frit includes zinc boron silicate. Differing from the conventional product, which includes lead boron silicate, the glass frit, which includes zinc boron silicate, reacts with the nitride in the ceramic substrate and has a small amount of oxide that
15 produces nitrogen gas. Accordingly, even if the conductive layer is formed using a material including zinc boron silicate, a large amount of nitrogen gas is not produced and the expansion of the conductive layer is suppressed.

20 It is preferred that the noble metal grains is at least one selected from gold grains, silver grains, platinum grains, and palladium grains. Since the used metal grains resists oxidization even when exposed to high temperatures and has a sufficiently large resistance, a conductive layer
25 optimal for functioning as a resistor that produces heat is easily formed.

 A second perspective according to the present invention is a conductive paste including ruthenium oxide,
30 glass frit, and noble metal grains.

 A third perspective according to the present invention is a conductive paste including ruthenium oxide, bismuth or

its oxide, glass frit, and noble metal grains.

BRIEF DESCRIPTION OF THE DRAWINGS

5 Fig. 1 is a schematic cross-sectional view showing a hot plate unit according to one embodiment of the present invention.

10 Fig. 2 is a partial enlarged cross-sectional view showing the hot plate unit of Fig. 2.

~~BEST MODE FOR CARRYING OUT THE INVENTION~~

15 A hot plate unit 1 according to one embodiment of the present invention will now be described with reference to Figs. 1 and 2.

20 The hot plate unit 1, which is shown in Fig. 1, is formed by the main elements of a casing 2 and a hot plate 3.

25 The casing 2 is a cup-like metal member having an opened portion 4, the cross-section of which is round, located at its upper portion. The casing 2 does not have to be cup-like and may have an opened bottom. A hot plate 3 is attached to the opening 4 by means of an annular seal ring 14. A lead wire hole 7 for receiving current supplying lead wires 6 extends through the peripheral part of the bottom portion 2a of the casing 2.

30 The hot plate 3 of the present embodiment, which is formed from a ceramic substrate 9, is used to dry a silicon wafer W1, to which a photosensitive resin is applied, at 50°C to 800°C or to perform heating during sputtering.

It is preferred that a ceramic nitride substrate or a ceramic carbide substrate be selected as the ceramic substrate 9 since they have superior heat resistance and high thermal conductivity properties. More specifically, it is preferred that an aluminum nitride substrate, a silicon nitride substrate, a boron nitride substrate, a titanium nitride substrate, a silicon carbide substrate, a boron carbide substrate, or a titanium carbide substrate be selected. Among these substrates, it is most preferred that the aluminum nitride substrate be selected and next preferred that the silicon nitride substrate be selected. This is because these substrates have the highest thermal conductivity among the above ceramic nitrides.

The ceramic substrate 9 is disk-like, has a thickness of about 1mm to 100mm, and has a diameter that is slightly smaller than the outer dimension of the casing 2.

Referring to Figs. 1 and 2, a wiring resistor 10, which serves as a conductive pattern layer, is formed in a concentric or spiral manner on the lower surface of the plate-like substrate 9. Pads 10a are formed on an end of the wiring resistor 10. The wiring resistor 10 and the pads 10a are formed by printing, heating, and bonding a conductive paste (noble metal paste) P1 on the surface of the ceramic substrate 9. In the hot plate 3 of the present embodiment, the surface for heating the silicon wafer W1 is located on the opposite side of the conductive pattern layer formation layer, or on the upper surface. Such structure has an advantage in that a difference in temperature between locations does not occur in the hot plate 3 and in that the silicon wafer W1 is uniformly heated.

The wiring resistor 10 and the pads 10a of the present embodiment that are formed from the noble metal paste P1 includes noble metal grains as a main component and glass frit, or the like, as a secondary component. It is preferred that the noble metal grains used in the present embodiment have an average grain diameter of $6\mu\text{m}$ or less and be flake-like.

It is preferred that the flake-like noble metal grains be selected from one of gold grains (Au grains), silver grains (Ag grains), platinum grains (Pt grains), and palladium grains (Pd grains). These noble metals relatively resist oxidation even if they are exposed to high temperatures and have a sufficiently large resistance when energized and heated.

Referring to Figs. 1 and 2, the basal end of a terminal pin 12, which is made of a conductive material, is soldered to each pad 10a. This electrically connects each terminal pin 12 to the wiring resistor 10. Sockets 6a, which are located on the distal end of the lead wires 6, are fit into the distal ends of the terminal pins 12. Accordingly, the temperature of the wiring resistor 10 increases and heats the entire hot plate 3 when current is supplied to the wiring resistor 10 via the lead wires 6 and the terminal pins 12.

An example of the procedures for manufacturing the hot plate 3 will now be briefly described.

A sintering-aid agent, such as yttria, and a binder are added as required to ceramic grains to prepare a mixture.

The mixture is uniformly kneaded into, for example, three rolls. The kneaded material is used to press mold plate-like molding products having a thickness of 1 to 100mm.

5 Holes are punched or drilled in the molded product to form pin insertion holes, which are not shown in the drawings. After the hole forming process, the molded product is dried. Then, the molded product undergoes provisional baking and main baking so that it is completely sintered.
10 This forms the ceramic sinter substrate 9. It is preferred that the baking process be performed in a hot-press apparatus and that the baking process be performed at a temperature of about 1500°C to 2000°C. Afterward, the ceramic substrate 9 is cut into a disk-like shape having a
15 predetermined diameter (in the present embodiment, 230mm ϕ) and undergoes surface grinding, preferably with a hub grinder.

 After the above process, the noble metal paste P1,
20 which has been prepared beforehand, is uniformly applied to the lower surface of the ceramic substrate 9, preferably through screen-printing.

 In addition to noble metal grains, the noble metal
25 paste P1 used here includes ruthenium oxide, glass frit, a resin binder, and a solvent. The noble metal paste P1 may also include bismuth or bismuth oxide.

 It is preferred that 40wt% to 60wt% of noble metal
30 grains and 10wt% to 30wt% (however, 10wt% or greater with respect to noble metal) of glass frit be included in the noble metal paste P1.

If the amount of noble metal grains is too large, an increase in the ratio of the conductive components in the wiring resistor 10 may decrease the specific resistance. On the other hand, if the amount of noble metal grains is too small, although the specific resistance increases in a preferable manner, the amount of glass frit relatively increases. Thus, the expansion is apt to occur. The wiring resistor 10 is also apt to expand when the amount of glass frit is too large. On the other hand, if the amount of glass frit is too small, the expansion rarely occurs but it becomes difficult to increase adhesion.

It is preferred that bismuth (Bi) or bismuth oxide (Bi_2O_3) be included in the noble metal paste P1. In other words, test results have shown that by adding these substances, expansion is suppressed even if the application amount of the added glass frit is large (10% or greater relative to the noble metal). Further, adhesion of the wiring resistor 10 is improved.

These substances are relatively easily oxidized and reduced in comparison to other oxides. It is presently presumed that such properties contribute to suppress expansion and enhance adhesion in one way or another.

When selecting, for example, aluminum nitride, as the substrate material, bismuth oxide reacts with the aluminum nitride when the paste is bonded and produces alumina and nitrogen gas. Thus, the bismuth oxide functions as an oxidization agent of the aluminum nitride. Further, when exposed to air, bismuth is easily oxidized into bismuth oxide.

Additionally, when selecting, for example, silicon nitride as the substrate material, bismuth oxide reacts with silicon nitride when the paste is bonded and produces silica and nitrogen gas. Thus, the bismuth oxide functions as an oxidization agent of the silicon nitride. In the same manner, bismuth may be considered as an oxidization agent of the silicon nitride.

It is preferred that about 1wt% to 10wt% of bismuth or bismuth oxide be included in the noble metal paste P1, more preferred that about 5wt% to 10wt% be included, and especially preferred that about 7wt% to 8wt% be included. If the content of bismuth or bismuth oxide is too small, the effect obtaining by adding bismuth or bismuth is insufficient. Thus, the expansion may not be prevented and the adhesion may not be significantly improved. On the other hand, if the content of bismuth and bismuth oxide is too large, the noble metal does not mix with the bismuth or the bismuth oxide and result in different resistances.

Further, the noble metal paste P1 must include ruthenium oxide (RuO_2). It is considered that together with bismuth or bismuth oxide, ruthenium oxide appropriately suppresses reaction between the glass frit and the aluminum nitride of the ceramic substrate and prevents the generation of reaction gas.

It is preferred that about 0.5wt% to 5wt% of ruthenium oxide be included in the noble metal paste P1, and particularly preferred that about 1wt% to 2wt% be included.

If the amount of ruthenium oxide is too small, the suppression of the reaction caused by bismuth or bismuth

oxide may not be guaranteed and the prevention of the expansion when the added amount of glass frit is too large may not be guaranteed. On the other hand, reaction caused by bismuth or oxide bismuth may be excessively suppressed when the amount of ruthenium oxide is too large, and the adhesion may not be improved when the added amount of glass frit is too large. It is preferred that the content of ruthenium oxide be less than or equal to the content of bismuth or bismuth oxide.

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It is preferred that glass frit including zinc boron silicate (SiO_2 : B_2O_3 : ZnO_2) be used, and especially preferred that the glass frit includes zinc boron silicate as a main component. More specifically, it is preferred that a small amount of oxide be added to the zinc boron silicate.

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Specific examples of oxides include aluminum oxide (Al_2O_3), yttrium oxide (Y_2O_3), lead oxide (PbO), cadmium oxide (CdO), chromium oxide (Cr_2O_3), and copper oxide (CuO). One of these oxides or a combination of two or more of these oxides may be added to the zinc boron silicate. During the bonding of the paste, these oxides function as an oxidization agent of the substrate material and are thus reduced.

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It is preferred that the weight ratio of each of the above listed oxides be $1/20$ times to $1/5$ times the weight ratio of zinc boron silicate, which serves as a base. If the weight ratio is too small, the percentage of the above oxides in the glass frit increases. As a result, the expansion caused by nitrogen gas may not be sufficiently prevented. On the other hand, if the weight ratio is too large, the percentage of the above oxides in the glass frit decreases. As a result, the adhesion of the wiring resistor may not be sufficiently increased.

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The noble metal paste P1 also includes 2wt% to 15wt% of a resin binder, which serves as an organic vehicle, and 10wt% to 30wt% of a solvent. Examples of the resin binder are, for example, the cellulose group such as ethyl cellulose. The solvent is a component added to improve the printing and dispersion characteristics. Specific examples of the solvent are the acetate group, the cellosolve group such as butyl cellosolve, or the Carbitol group such as butyl Carbitol. One or a combination of two or more of these solvents may be used.

When the noble metal paste P1 applied to the ceramic substrate 9 is heated for a predetermined time at a temperature of about 750°C, the solvent in the noble metal paste P1 volatilizes and bonds the wiring resistor 10 and the pads 10a to the ceramic substrate 9. Fused glass frit has a tendency to move toward the ceramic substrate 9. Contrarily, the noble metal grains have a tendency to move away from the ceramic substrate 9.

Subsequently, the pads 10a are connected to the terminal pins by a solder S1 to complete the hot plate 3. Then, the hot plate 3 is attached to the opening 4 of the casing 2 to complete the desired hot plate unit 1 of Fig. 1.

(Examples and Comparative Examples)

[Preparation of Samples 1 to 8]

In examples 1 to 5 and comparative examples 1 to 3, 4 parts by weight of Y_2O_3 (average grain diameter $0.4\mu m$) and 8 parts by weight of an acrylic resin binder (manufactured by

Mitsui Chemicals, product name: SA-545, acid number 1.0) were added to 100 parts by weight of aluminum nitride powder (average grain diameter $1.1\mu\text{m}$) and mixed. The mixture produced in this manner was uniformly kneaded. The kneaded product was put into a press mold and pressed to form a plate-like molded product.

Then, after forming holes and performing a drying process, the molded product was degreased for four hours at a temperature of 350°C for four hours to thermally decompose the binder. Further, the degreased molded body was baked in a hot-press for three hours at a temperature of 1600°C to produce the aluminum nitride substrate, or the ceramic substrate 9. The pressure of the hot press was $150\text{kg}/\text{cm}^2$.

Then, after cutting the substrate and performing surface grinding, a paste applying process was performed. In the process, the noble metal paste P1, the composition of which is described below, was used and applied to a thickness of about $25\mu\text{m}$. Eight types of samples were prepared in accordance with the above procedure (refer to table 1).

Only one type of noble metal grains, that is, silver grains, which were flake-like and had an average grain diameter of $5\mu\text{m}$, was used. The added amount of the silver grains in the silver paste, which served as the noble metal paste P1, was 45wt% in sample 5, 50wt% in samples 2, 4, and 7, 55wt% in samples 1, 3, and 6, and 70wt% in sample 8.

The glass frit included zinc boron silicate as a base (i.e., a zinc-containing material was used as the glass frit). The amount of glass frit added in each sample is

shown in table 1, and the specific composition of each sample is shown in the lower rows of table 1. The amount of bismuth and ruthenium oxide that was added in each sample is as shown in table 1.

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Ethyl cellulose was selected as the binder, and butyl Carbitol was selected as the solvent.

10 Although bismuth was added, ruthenium oxide was not added in samples 6, 7, and 8. Thus, samples 6, 7, 8 do not satisfy the optimal conditions of the present embodiment. Further, in sample 8, the amount of glass frit is small in comparison to the amount of silver grains. Thus, sample 8 does not satisfy the optimal conditions of the present
15 embodiment. Accordingly, samples 1 to 5 correspond to examples 1 to 5, and samples 6 to 8 correspond to comparative examples 1 to 3.

[Comparison Test and Results]

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In each of the eight samples, the paste was printed to and bonded on the ceramic substrate 9, and two square millimeter test patterns were formed at multiple locations. The expansion of the test patterns was confirmed through
25 observation with the naked eye and with an optical microscope. A tensile strength test was performed on test patterns that did not expand, and the average value of the measured values (kgf/2mm \square) was calculated. Simultaneously, the resistance was measured with a Multimeter, and the
30 specific resistance ($\mu \Omega \cdot \text{cm}$) of the patterns was calculated from the measured length and the cross-sectional area of the patterns. The target value of the specific resistance was 10 $\mu \Omega \cdot \text{cm}$. The results of the experiments are shown in table 1.

Table 1

Sample No.	Ag grains (wt%)	Added Amount of Bi (wt%)	Added Amount of Glass Frit (wt%)	Added Amount of RuO ₂ (wt%)	Expansion	Tensile Strength (kgf/2mm □)	Specific Resistance ($\mu \Omega \cdot \text{cm}$)
1 (Example 1)	55	8	20	2	None	10.2	50
2 (Example 2)	50	7	18	1	None	9.1	50
3 (Example 3)	55	1	20	0.5	None	8.9	50
4 (Example 4)	50	10	20	5	None	9.3	50
5 (Example 5)	45	8	30	2	None	10.1	60
6 (Comparative Example 1)	55	6	15	0	Confirmed	-	20
7 (Comparative Example 2)	50	4	20	0	Confirmed	-	30
8 (Comparative Example 3)	70	3	3	0	None	8.2	5

Note: glass frit includes 80wt% of zinc boron silicate and 20wt% of Al₂O₃,

As apparent from table 1, absolutely no expansion was confirmed in each of embodiments 1 to 5. Further, sufficient tensile strength was obtained, and the specific strength was greater than the target value. In comparison examples 1 and 2, expansion was confirmed and the pattern formation accuracy was unsatisfactory. In comparison example 3, expansion was not confirmed and sufficient tensile strength was obtained. However, the specific strength was not as high as the target value.

[Preparation of Sample 9]

In example 6, 20 parts by weight of Y_2O_3 (average grain diameter $0.4\mu m$), 15 parts by weight of Al_2O_3 (average grain diameter $0.5\mu m$), 20 parts by weight of SiO_2 (average grain diameter $0.5\mu m$), and 8 parts by weight of an acrylic resin binder (manufactured by Mitsui Chemicals, product name: SA-545, acid number 1.0) were mixed with 45 parts by weight of silicon nitride powder (average grain diameter $1.1\mu m$).

The mixture obtained in this manner was uniformly kneaded. The kneaded product was put into a press mold and pressed to form a plate-like molded product.

Then, after forming holes and performing a drying process, the molded product was degreased for four hours at a temperature of $350^\circ C$ for four hours in a nitrogen atmosphere to thermally decompose the binder. Further, the degreased molded body was baked in a hot-press for three hours at a temperature of $1600^\circ C$ to produce a silicon nitride substrate, or the ceramic substrate 9. The pressure of the hot press was $150 kg/cm^2$.

Then, after cutting the substrate and performing surface grinding, a paste applying process was performed. In the process, the noble metal paste P1, the composition of which is described below, was used and applied to a thickness of about $25\mu\text{m}$. Bismuth oxide was used instead of bismuth.

Noble metal grains: 100 parts by weight of palladium grains (Pd-730 manufactured by Shoei Chemical Inc.)

Glass Frit: 2.0 parts by weight of SiO_2 , 5.0 parts by weight of B_2O_3 , 10.0 parts by weight of ZnO , and 1.2 parts by weight of PbO

Bi_2O_3 : 1.1 parts by weight

RuO_2 : 1.0 parts by weight

Resin binder: 3.4 parts by weight

Butyl Carbitol serving as a solvent: 17.9 parts by weight

The applied noble metal paste P1 was heated at a temperature of about 750°C for a predetermined time to bond the wiring resistor 10 and the pads 10a and complete sample 9, which corresponds to the hot plate 3 of example 6.

[Comparison Test and Results]

The same comparison test as that conducted on examples 1 to 5 and comparison examples 1 to 3 was performed on sample 9. Expansion of the wiring resistor 10 was not

confirmed. Further, the tensile strength test was 11.5kgf/2mm² and greater than examples 1 to 5. The specific resistance of the patterns was 110 $\mu\Omega\cdot\text{cm}$ and much greater than the target value.

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Accordingly, the examples of the present embodiment have the advantages described below.

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(1) In the hot plates 3 of examples 1 to 6, the added amount of glass frit is adjusted at 10wt% or greater relative to the noble metal grains to increase the specific resistance of the conductive pattern layer (i.e., the wiring resistor 1 and the pads 10a).

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Accordingly, the ratio of the conductive components in the wiring resistor 10 is small and the specific resistance is extremely large. Thus, the hot plate 3 has a superior heating capability. Further, such hot plate 3 is optimal when used, for example, for heating at high temperatures (200°C or greater).

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(2) The wiring resistor 10 and the pads 10a of the hot plate 3 in examples 1 to 5 are formed from ruthenium oxide, bismuth, glass frit, and silver grains. Further, the wiring resistor 10 and the pads 10a of the hot plate 3 in example 6 are formed from ruthenium oxide, bismuth oxide, glass frit, and palladium grains.

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Accordingly, the synergism of bismuth or its oxide and ruthenium oxide prevents the expansion of the wiring resistor 10 even if the added amount of glass frit is relatively large to increase the specific resistance. Therefore, the wiring resistor 10 does not expand and has a

large specific resistance (i.e., $10\mu\Omega\cdot\text{cm}$). Further, since the wiring resistor 10 includes bismuth or bismuth oxide, the wiring resistor 10 has superior adhesion. Thus, the hot plate 3 not only has a superior heating capability but also has superior pattern formation accuracy and high reliability.

In examples 1 to 5, the bismuth in the noble metal paste P1 may be replaced by the same amount of bismuth oxide. In example 6, the bismuth oxide in the noble metal paste P1 may be replaced by the same amount of bismuth.

(3) In examples 1 to 5, an aluminum nitride substrate, which has especially superior heat resistance and high thermal conductivity, is used as the ceramic substrate 9. Thus, the hot plate 3 is practical since it may be used under high temperatures.

(4) The noble metal paste P1 used in examples 1 to 6 includes 1wt% to 10wt% of bismuth or bismuth oxide, which is an optimal amount. Thus, expansion is prevented, adhesion is improved, and the specific resistance is increased.

(5) The noble metal paste P1 used in examples 1 to 6 includes 0.5wt% to 5wt% of ruthenium oxide, which is an optimal amount. Thus, expansion is prevented, adhesion is improved, and the specific resistance is increased.

The embodiment of the present invention may be modified as described below.

Spherical noble metal grains may be used in lieu of the flake-like noble metal grains. Further, instead of using only one type of the noble metal grains, two or more types

of noble metal grains (e.g., flake-like grains and spherical grains) may be mixed and used.

5 The oxide included in the glass frit, the base of which is zinc boron silicate, is not limited to Al_2O_3 , which is used in the examples of the above embodiment, and may, of course, be changed.

10 The ceramic substrate 9 is not limited to products manufactured through a press molding and may be manufactured, for example, by performing sheet molding with a doctor blade apparatus. When performing sheet molding, the wiring resistor 10 may, for example, be arranged between superimposed sheets. Thus, the high temperature hot plate 3
15 is manufactured in a relatively simple manner.

20 The conductive pattern layer is not limited to the wiring resistor 10 and the pads 10a used in the above embodiment and may be other structures.

 The noble metal paste P1 need not be screen printed on the ceramic substrate 9. For example, the noble metal paste P1 may be stamped on the ceramic substrate 9.